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Experiment No. 1

Aim: Study of different types of physical layer wired/wireless connections
As a part of study you must include following aspects of connection

- Specifications including range, modulation etc.
- Scalability showing their applicability in various network architecture e.g LAN, WAN, MAN, HAN etc.
- Provide Schematic view of physical connector

Introduction:

The physical layer represents the first level of the hierarchy of the reference model. The physical layer in the OSI Model (Open Systems interconnection model) is the lowest layer and is used for transmitting data in its basic form: bit-level. It is responsible for the actual physical connection between the devices.

Physical layer in the OSI model plays the role of interacting with actual hardware and signalling mechanism. Physical layer is the only layer of OSI network model which actually deals with the physical connectivity of two different stations. This layer defines the hardware equipment, cabling, wiring, frequencies, pulses used to represent binary signals etc.

Physical layer provides its services to Data-link layer. Data-link layer hands over frames to physical layer. Physical layer converts them to electrical pulses, which represent binary data. The binary data is then sent over the wired or wireless media.

The functions of the physical layer are :

1. **Bit synchronization:** The physical layer provides the synchronization of the bits by providing a clock. This clock controls both sender and receiver thus providing synchronization at bit level.
2. **Bit rate control:** The Physical layer also defines the transmission rate i.e. the number of bits sent per second.
3. **Physical topologies:** Physical layer specifies the way in which the different, devices/nodes are arranged in a network i.e. bus, star or mesh topology.
4. **Transmission mode:** Physical layer also defines the way in which the data flows between the two connected devices. The various transmission modes possible are: Simplex, half-duplex and full-duplex.

The transmission medium can either be wired or wireless. Physical layer components in a wired model include cables and connectors that are implemented for carrying data from one place to another. Data is transmitted in the form of electromagnetic signals, which translates to a stream of bits. Over the past few years, there has been rapid growth in wireless data transmission as well. Due to the availability of internet, Wi-Fi and Bluetooth communications are becoming a norm.

Wired physical layer connections:

1. **Fiber Optic Cable**[1][2][3][4][5][6]

Fiber optic is a very powerful media, allowing data transfer at extremely high speeds and for very long distances. Fiber-optic cable is a type of cable using glass or plastic threads (fibers) to transmit data. Fiber-optic cable consists of a bundle of glass threads, each of which transmits messages via light waves. This glass is encased in cladding and coating, reinforced by strengthening fibers and further wrapped within a cable jacket.

There are two types of fiber optic cable: Single Mode Fiber (SMF) and Multi Mode Fiber (MMF).

1. Single-mode Fiber (SMF) uses a single ray of light to carry transmission over long distances. Please click next link to learn more about single mode fiber (SMF).

2. Multi-mode Fiber (MMF) uses multiple rays of light simultaneously with each ray of light running at a different reflection angle to carry the transmission over short distances. Multi-mode fiber cables can transmit data at 100 Mbps (megabits per second) for distances up to 2 kilometres (100Base-FX), 1 Gbps up to 1000 meters (1 kilometre), and 10 Gbps up to 550 meters.

Scalability:

Fiber optics are more scalable, as it's simple to install new equipment can over original fiber. Wavelengths can be turned on or off on demand, which allows for the easy provisioning of services and quick scaling for a growing business.

Optical network segments are categorized with respect to the size of the area they cover:

- Long-haul core networks, also known as Wide Area Networks (WAN) or interchange carrier (IXC) public networks.
- Edge/regional/metro networks, also known as Metropolitan Area Network (MAN) or local exchange carrier (LEC).
- Access networks providing peripheral links ("last-mile access") to the end-users.

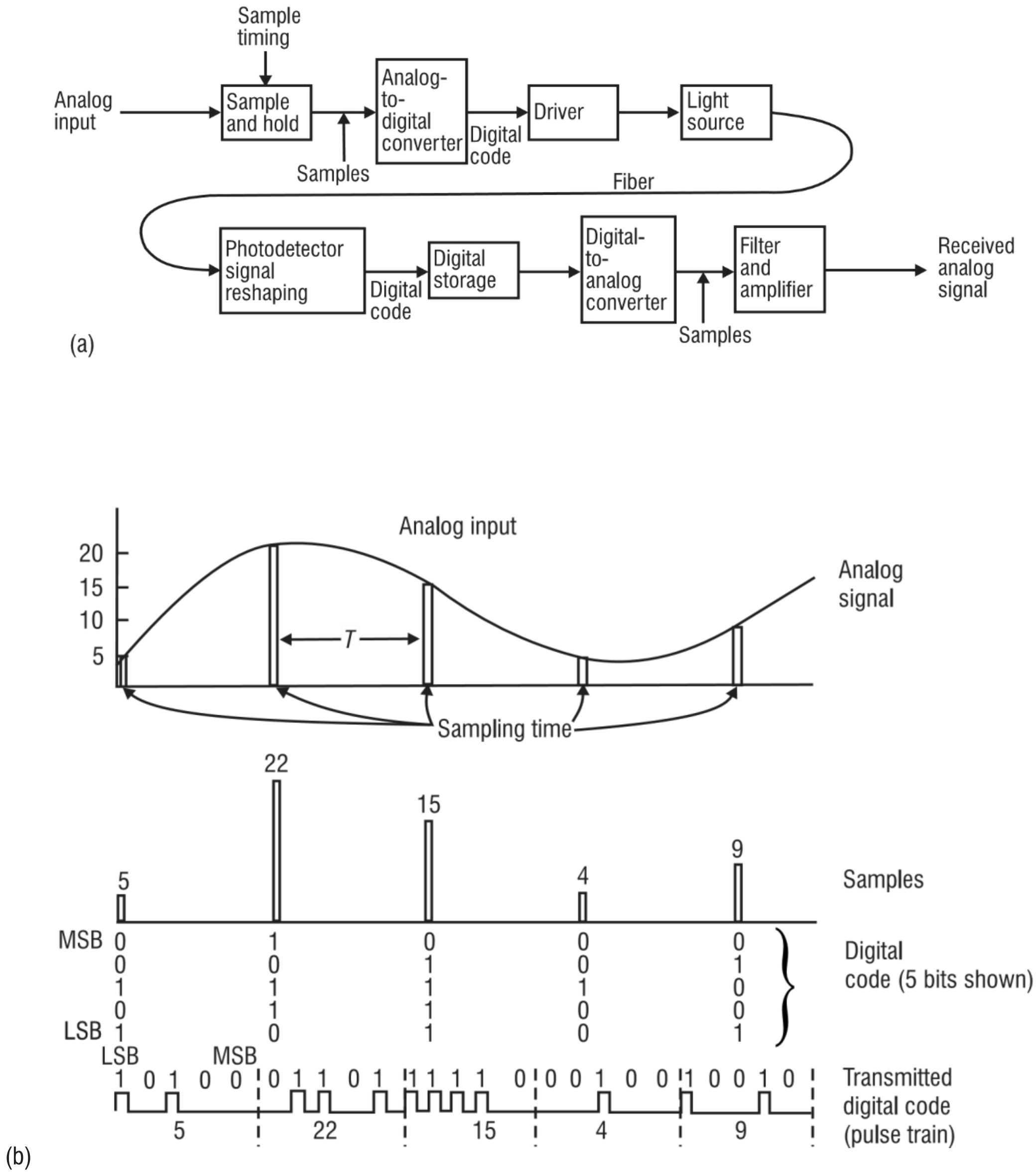
Modulation and encoding:

Optical fiber modulation techniques are required to either encode information or extract information from the fiber guided beam. Information in a fiber optic system can be transmitted in one of two ways: analog or digital

The **transmitter** converts the electrical input signal to an optical signal. Its **drive circuit** varies the current flow through the light source, which in turn varies the irradiance of the source. The process of varying the irradiance as a function of time is called **modulation**.

- **Analog modulation** consists of changing the light level in a continuous manner. The performance of a system using analog modulation is limited by random noise in the system, either in the detector, which converts the modulated light signal back into an electrical signal, or in the system itself. Noise determines the smallest signal that can be transmitted and how faithful the reproduced signal is to the original signal.

  1. **Pulse Code modulation:** Pulse code modulation (PCM) is the process of converting an analog signal into a 2^n -digit binary code. Information is transmitted as a series of pulses. The digital pulse-code-modulated signal is coupled into a fiber. The fiber end is positioned by a connector to maximize the input power.



- In **digital modulation** information is encoded into a series of pulses, separated by spaces. The absence or presence of a pulse at some point in the data stream represents one bit of information. Faithful reproduction of signal intensity is not required. Pulses must only be transmitted with sufficient power for the detector to determine the presence or absence of a pulse. This makes a system using digital modulation superior when sources of noise are present. Performance in digital systems is given in terms of the bit error rate, the average ratio of the number of errors to the number of transmitted pulses. State-of-the-art systems have bit error rates of less than 10^{-9}.

  - Many coding schemes are used in digital communication systems, each with its own benefits and drawbacks. The most common encoding schemes are the return-to-zero (RZ) and non-return-to-zero (NRZ). The NRZ encoding scheme, for example, requires only one transition per symbol, whereas RZ format requires two transitions for each data bit

    Depending on the application, any of the code formats may be more appropriate than the others. For example, in synchronous transmission systems in which large amounts of data are to be sent, clock synchronization between the transmitter and receiver must be ensured. In this case **Manchester encoding** is used. The transmitter clock is embedded in the data. The receiver clock is derived from the guaranteed transition in the middle of each bit

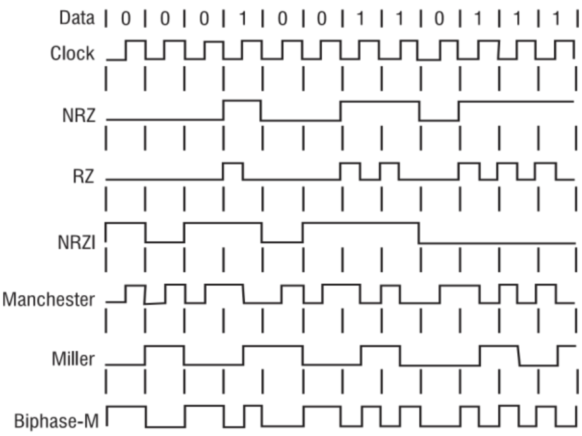
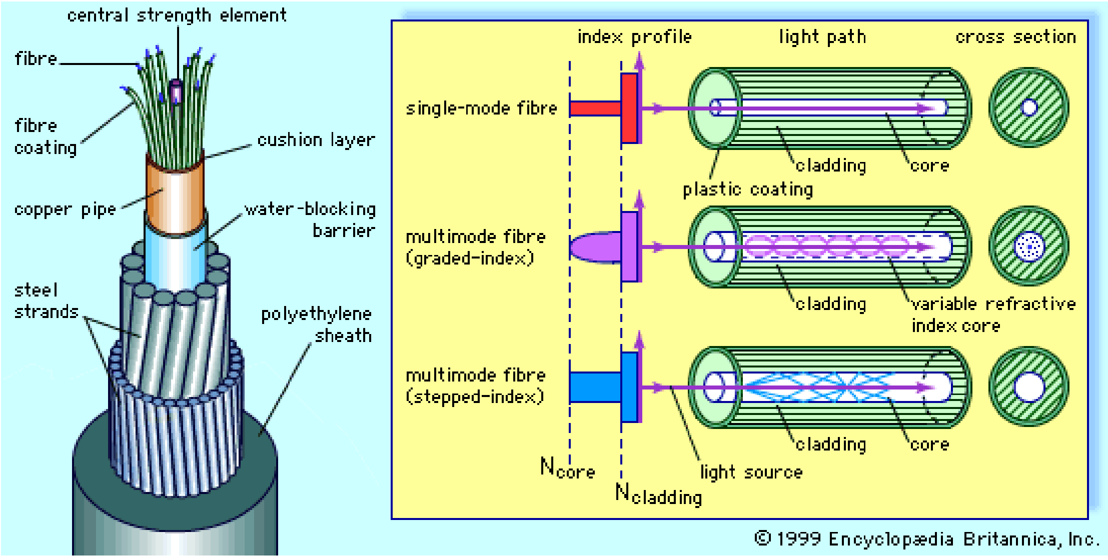


Figure 8-11 *Different encoding schemes*

Format	Symbols Clocking per Bit	Self-	Duty Factor Range (%)
NRZ	1	No	0-100
RZ	2	No	0-50
NRZI	1	No	0-100
Manchester (Biphase L)	2	Yes	50
Miller	1	Yes	33-67
Biphase M (Bifrequency)	2	Yes	50

Schematic view:



2. Unshielded Twisted Pair[7][8][9]

UTP Cable is a shorter way of saying unshielded twisted pair. This is one of the least expensive wires and works for basic needs of phone systems so it is one of the most commonly installed in residential industries

Inside a UTP cable is up to four twisted pairs of copper wires, enclosed in a protective plastic cover, with the greater number of pairs corresponding to more bandwidth. The two individual wires in a single pair are twisted around each other, and then the pairs are twisted around each other, as well. This is done to reduce crosstalk and electromagnetic interference, each of which can degrade network performance. Each signal on a twisted pair requires both wires.

Twisted pairs are color-coded to make it easy to identify each pair.

Scalability:

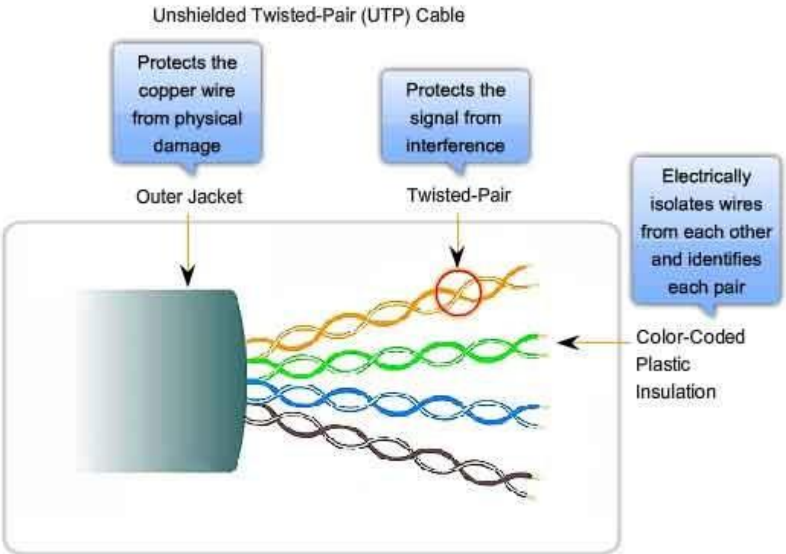
UTP cables are mostly used for LAN networks. They can be used for voice, low-speed data, high-speed data, audio and paging systems, and building automation and control systems. UTP cable can be used in both the horizontal and backbone cabling subsystems.

Most of the time though, UTP cables are used in computer networking and in modern Ethernet solutions. It is also used in data networks as networks which have short or medium length will save money over optical fiber or coaxial cable.

Speed and Range:

UTP supports speeds ranging from 10 Mbps to 10Gbps up to a distance of 100 meters

Schematic view:



3. **Shielded Twisted Pair**[10][11][12][13]

Shielded Twisted Pair (STP) cables additionally have an overall conducting metallic shields covering four twisted pair wires. There may be another conducting metallic shields covering individual twisted pairs also. These metallic shields blocks out electromagnetic interference to prevent unwanted noise from the communication circuit.

Drain wires are also used in Shielded Twisted Pair (STP) cables together with metallic shields for grounding purpose. The drain wire provides a low-resistance connection to shield for better grounding. The main purpose of drain wire is to carry away unwanted interference noise to ground.

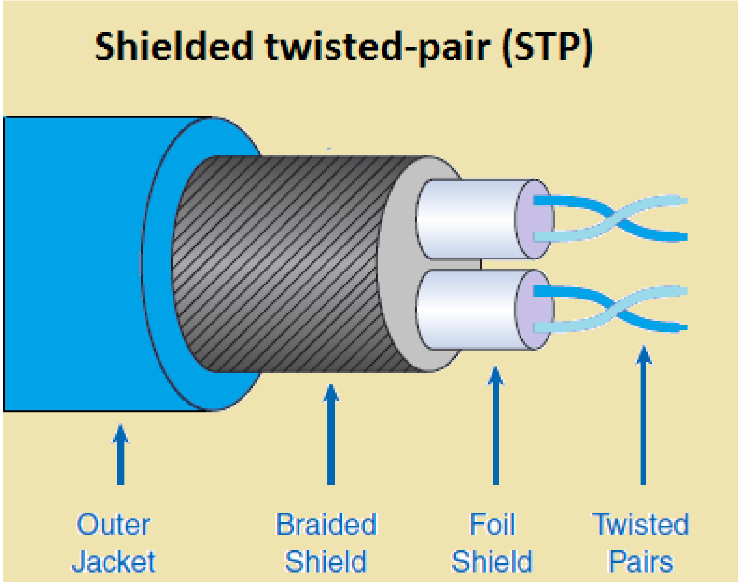
Scalability:

STP cables are often used in LAN Ethernet networks, particularly fast-data-rate Ethernets.

Range:

STP can achieve the maximum transmission distance (cable length) of 100 meters.

Schematic view:



4. Ethernet[14][15][16]

Legacy Ethernet (10Base – X)

The 10Base-T UTP Ethernet and 10Base-2 Coax Ethernet were very popular in the early to mid 1990's when 100 Mbps network cards and hubs/switches were very expensive. Generally speaking, the 10Base-T and 10Base-2 standards are not used anymore today, The various types of !0 Base cables are

1. 10Base-T: The "T" refers to "Twisted Pair" physical medium that carries the signal.
2. 10Base2: This specification uses coaxial cable which is usually black, sometimes also called "Thinwire coax," "Thin Ethernet," or "RJ-58" cable.
3. 10Base5: his specification uses what's called "Thickwire" coaxial cable, which is usually yellow.
4. 10BaseF: This specification uses fiber optic cable

Speed and Range:

The number 10 represents the frequency in MHz (Megahertz). The 10 MHz speed translates to 10Mbit per second, which in theory means 1.2 Mbps. In practice though, you wouldn't get more than 800 kilobits per second (Kbps).

Modulation and Encoding:

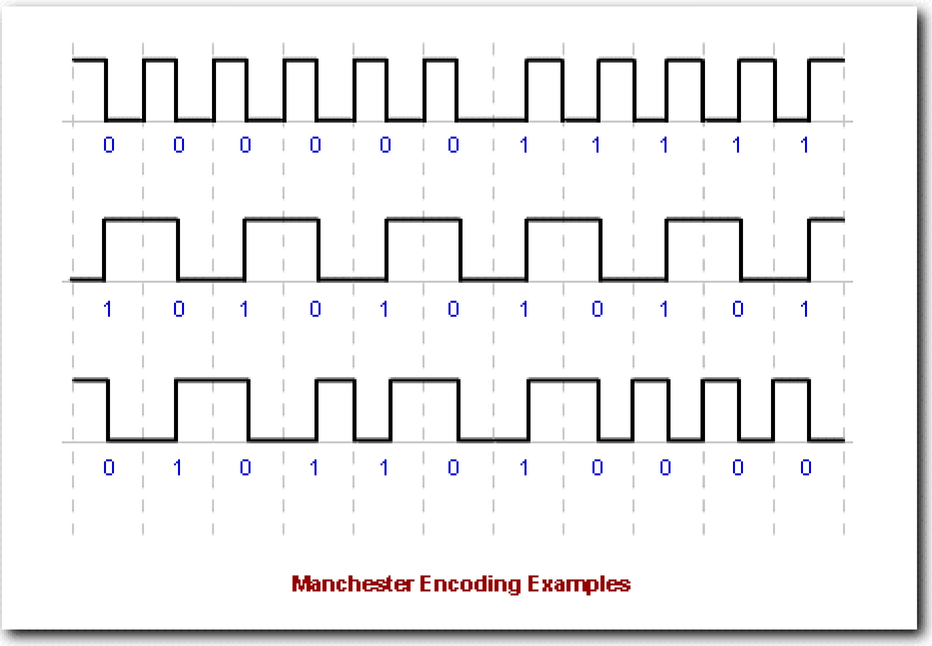
For 10BASE-5, 10BASE-2 and 10BASE-T, an encoding method called Manchester encoding is used because it provides a more reliable clocking signal. On 10BASE-5 Ethernet, the Manchester encoded signal is sent over thick coaxial cable. On 10BASE-2 Ethernet, the encoded signal is sent over thin coaxial cable. On 10BASE-T Ethernet, the encoded signal can be sent over Category 3 UTP cable, although any new installations implementing 10BASE-T today would probably use Category 5 or 5e.

Manchester encoding is an encoding method commonly used on Legacy Ethernet networks.

There are two rules to follow using this encoding method...

- To send a logic '0' data bit, **increase** the voltage up from 0 to +V in the middle of the bit period.
- To send a logic '1' data bit, **decrease** the voltage down from +V to 0 in the middle of the bit period.

We can see that a high-to-low transition represents a logic '0' data bit and a low-to-high transition represents a logic '1' data bit.



Fast Ethernet (100Base-TX and 100Base-FX)

The Fast Ethernet standard (IEEE 802.3u) was a marked improvement over Ethernet, raising the transmission speed from 10 Mbps to 100 Mbps and improving its error detection and correction rates. Fast Ethernet was quickly adopted, because it allowed faster access to video, multimedia and the internet. Fast Ethernet is most commonly found in networks using Category 5 (Cat-5) copper twisted-pair cable, but it also works with fiber-optic cable.

There are three types of Fast Ethernet, based on the cable being used.

- 100BASE-TX is for level 5 UTP cable.
- 100BASE-T4 is for level 3 UTP cable.
- 100BASE-FX is for fiber-optic cable

Speed and Range:

As the name suggests the speed of data transmission is 100 Mbps.

Each cable segment can cover a maximum distance of 100m

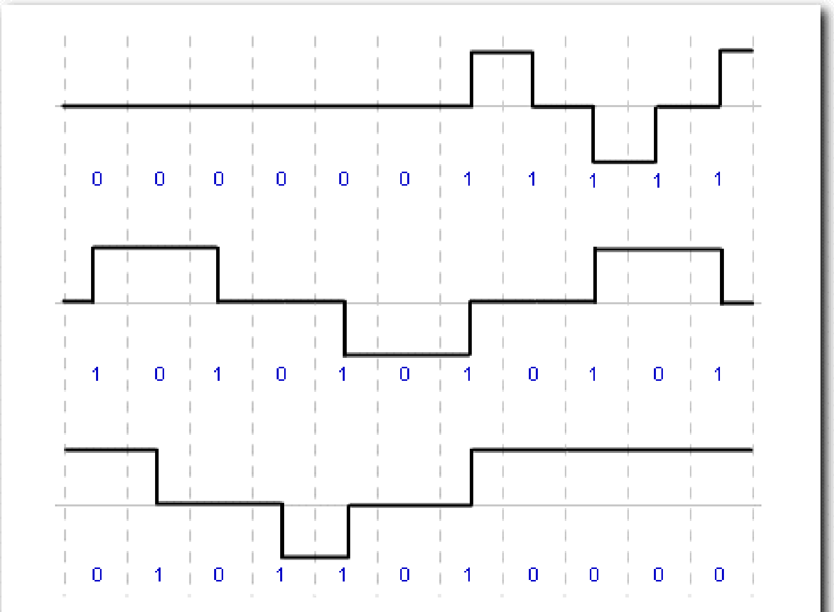
Modulation and Encoding:

MLT-3 encoding is used for 100BASE-TX and NRZ-I encoding is used for 100BASE-FX.

MLT-3 is an encoding method used on Fast Ethernet 100BASE-TX networks. It is similar to Manchester encoding in that a logic '1' is represented by a voltage transition. However, whereas a Manchester encoded signal uses a two-state waveform (0V or +V), an MLT-3 encoded signal uses a three-state waveform (-V or 0V or +V.)

The MLT-3 encoding method uses a pattern **+V, 0V, -V, 0V** and the rules to follow are...

- To send a logic '1' data bit, change the voltage level to the next level in the pattern
- To send a logic '0' data bit, keep the voltage level the same as the previous voltage level.



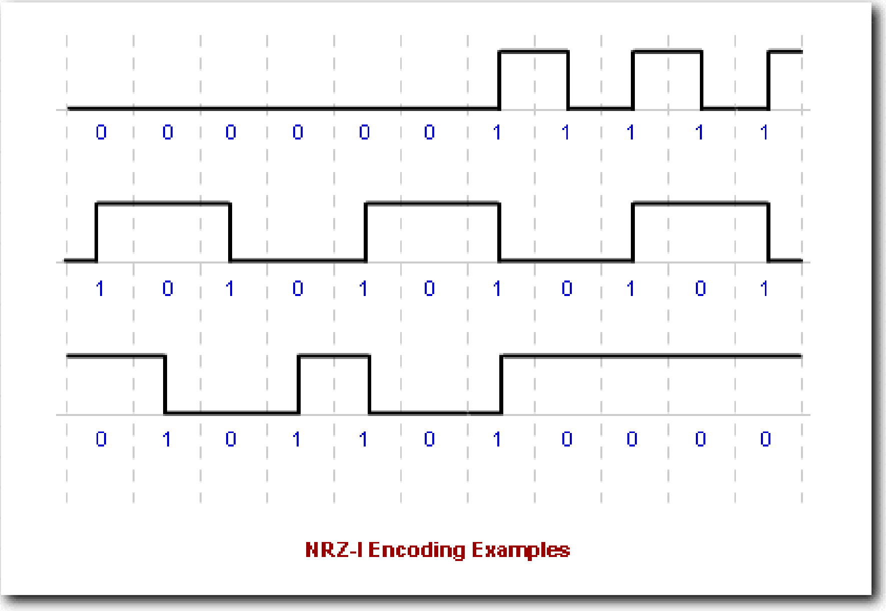
MLT-3 Encoding Examples

Non-Return-to-Zero Inverted (NRZ-I) is an encoding method used on Fast Ethernet 100BASE-FX networks.

There are two rule to follow using this encoding method...

- To send a logic '1' data bit, invert the voltage state from whatever it was before, in the middle of the bit period.
- To send a logic '0' data bit, leave the voltage state as it is.

The diagram below illustrates this:-



Gigabit Ethernet (1000 Mbps)

Gigabit Ethernet (IEE 802.3) was originally developed to be used as the backbone of large networks, connecting servers, routers and switches. It's 10 times faster than Fast Ethernet, with transfer rates of 1000 Mbps, or 1 Gbps. This was widely adopted with the advent of Voice over IP (VoIP) technology. Due to the lowering costs of this technology.

Speed and Range:

As the name suggests the speed of data transmission is 1000 Mbps or 1 Gbps.

If 1000BASE-SX fiber optic cable is used distances up to 550 meters are achieved while 1000BASE-LX achieves distances of up to 5,000 meters.

Modulation and encoding:

- For copper cable based Gigabit Ethernet (1000BASE-T), a pair of encoding methods was chosen, 8B1Q4 and 4D-PAM5.

  The 8B1Q4 encoding method converts each group of 8 data bits to four quinary symbols. Each quinary symbol is then line encoded using 4D-PAM5, which is a system that used five voltage levels, (similar to MLT-3 which uses three levels.)

  Since 2 bits are represented for each quinary symbol and the clock rate is set at 125MHz, this gives 250Mbps data per twisted pair and therefore 1000Mbps for the whole cable.

- For fiber optic based Gigabit Ethernet (1000BASE-X), a different pair of encoding methods was chosen, 8B10B and NRZ.

  The 8B10B encoding method is similar to 4B5B in that a group of bits are replaced with code words. The difference is that with 8B10B, each group of 8 bits is replaced with a 10-bit code word. This is followed by simple NRZ encoding

10 Gigabit Ethernet (10,000 Mbps)

10 Gigabit Ethernet (IEEE 802.3ae) is the latest Ethernet standard and, with a transfer rate of 10 Gbps, or 10,000 Mbps, it's 10 times faster than Gigabit Ethernet.
10 Gigabit Ethernet is primarily used as network backbones or in networks requiring extremely high data throughput rates.

Speed and Range:

As the name suggests the speed of data transmission is 10 Gbps

The maximum transmission distance depends on the type of fiber being used.
10GBASE-SR multimode fiber can be used for distances up to 82m. 10GBASE-LX4 multimode fiber can be used for distance up to 300m, whereas single-mode fiber can run to longer distances of up to 10km. 10GBASE-LR single-mode fiber can also be used for distances up to 10km. 10GBASE-EW single-mode fiber can be used really long distances - up to 40km.

Modulation and encoding:

10 Gigabit Ethernet 10GBASE-X data is encoded twice. Sometimes 8B10B encoding is used first, sometimes 64B/66B. The variety of line encoding applied second depends on the fiber used.

- 10GBASE-SR: Uses a short wavelength and 64B/66B encoding
- 10GBASE-LX4: Uses a long wavelength multiplexed into into four wavelengths of light transmitted simultaneously over a single pair of fiber optic cables. 8B/10B encoding is used.
- 10GBASE-LR and 10GBASE-ER: Uses long wavelengths and 64B/66B encoding

- 10GBASE-SW, 10GBASE-LW and 10GBASE-EW: Works with SONET OC-STS-192 equipment.

5. USB[17][18][19]

Universal Serial Bus (**USB**) is an industry standard that establishes specifications for cables and connectors and protocols for connection, communication and power supply (interfacing) between computers, peripherals and other computers.[3] A broad variety of USB hardware exists, including several different connectors, of which USB-C is the most recent.

Released in 1996, the USB standard is currently maintained by the USB Implementers Forum (USB-IF). There have been four generations of USB specifications: USB 1.x, USB 2.0, USB 3.x and USB4

Scalability:

USB possesses multiple limitations to its design:

- USB cables are limited in length, as the standard was intended for peripherals on the same table-top, not between rooms or buildings. However, a USB port can be connected to a gateway that accesses distant devices.
- USB has a strict tree network topology and master/slave protocol for addressing peripheral devices; those devices cannot interact with one another except via the host, and two hosts cannot communicate over their USB ports directly. Some extension to this limitation is possible through USB On-The-Go.
- A host cannot broadcast signals to all peripherals at once—each must be addressed individually. Some very high speed peripheral devices require sustained speeds not available in the USB standard.[5]
- While converters exist between certain legacy interfaces and USB, they may not provide full implementation of the legacy hardware. For example, a USB-to-parallel-port converter may work well with a printer, but not with a scanner that requires bi-directional use of the data pins.

Modulation and encoding:

The SuperSpeed bus (USB 3.0) 8b/10b encoding is used where each byte needs 10 bits to transmit, so the raw throughput is 500 MB/s. This also meant that normal data bytes were represented by 10 bits, and this caused a 20% overhead.

SuperSpeed Plus (USB 3.1 and USB 3.2) offers a new encoding scheme called 128b/132b. Thus 128 bits that are represented by 132 bits on the line. This results in only a 3% bandwidth overhead.

Speed:

- Released in January 1996, USB 1.0 specified data rates of 1.5 Mbit/s (Low Bandwidth or Low Speed) and 12 Mbit/s (Full Speed).

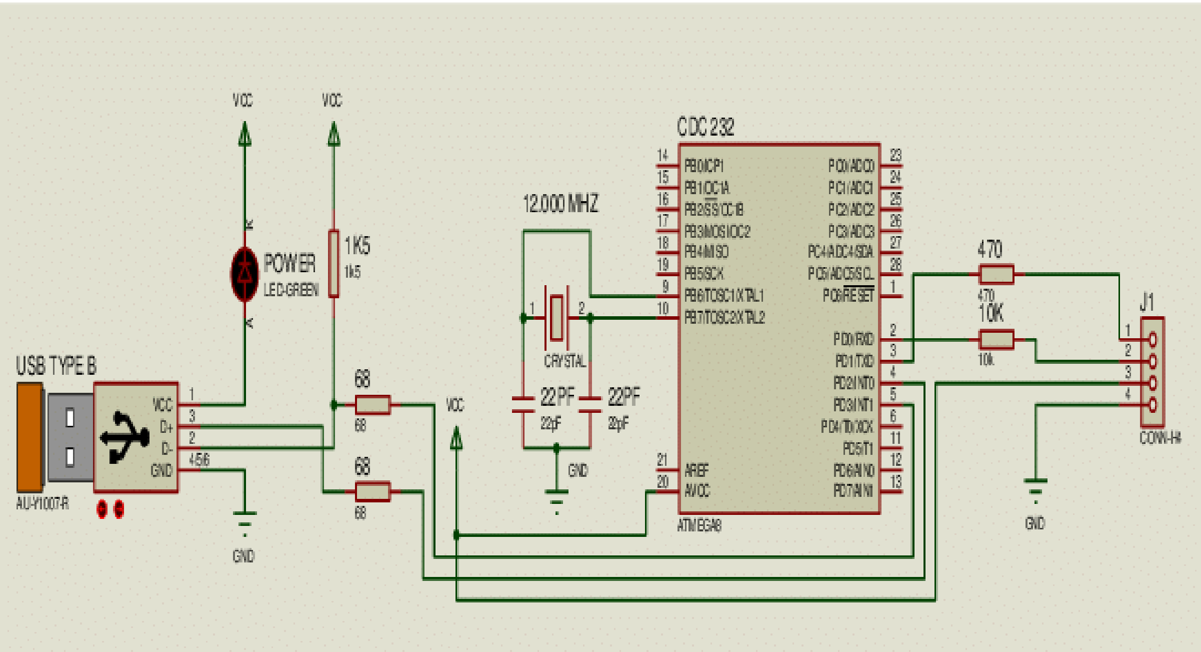
- USB 2.0 was released in April 2000, adding a higher maximum signalling rate of 480 Mbit/s (60 MB/s) named High Speed or High Bandwidth,
- USB 3.0 specification was released on 12 November 2008, USB 3.0 adds a SuperSpeed transfer mode, with associated backward compatible plugs, receptacles, and cables.

Specification	Name	Previous name	USB-IF branding	Data rate	Transfer speed
USB 3.0	USB 3.2 Gen 1	USB 3.1 Gen 1	SuperSpeed USB 5Gbps	5 Gbit/s	500 MB/s
USB 3.1	USB 3.2 Gen 2	USB 3.1 Gen 2	SuperSpeed USB 10Gbps	10 Gbit/s	1.21 GB/s
USB 3.2	USB 3.2 Gen 2 x 2	N/A	SuperSpeed USB 20Gbps	20 Gbit/s	2.42 GB/s

- The USB4 specification was released on 29 August 2019 by USB Implementers Forum.

  USB4 is based on the Thunderbolt 3 protocol specification.[36] It supports 40 Gbit/s throughput, is compatible with Thunderbolt 3, and backwards compatible with USB 3.2 and USB 2.0.

Schematic view:



Wireless physical layer connections:

1. **WiMax**[20][21][22][23]

WiMAX (Worldwide Interoperability for Microwave Access) is a family of wireless broadband communication standards based on the IEEE 802.16 set of standards, which provide multiple physical layer (PHY) and Media Access Control (MAC) options.

WiMAX operates similar to WiFi, but at higher speeds over greater distances and for a greater number of users. WiMAX has the ability to provide service even in areas that are difficult for wired infrastructure to reach and the ability to overcome the physical limitations of traditional wired infrastructure.

Scalability:

WiMAX is designed to efficiently support from one to hundreds of Consumer premises equipments (CPE)s, with unlimited subscribers behind each CPE. Flexible channel sizes from 1.5MHz to 20MHz.

WiMAX has a scalable physical-layer architecture that allows for the data rate to scale easily with available channel bandwidth. For example, a WiMAX system may use 128, 512, or 1,048-bit FFTs (fast Fourier transforms) based on whether the channel bandwidth is 1.25MHz, 5MHz, or 10MHz, respectively. This scaling may be done dynamically to support user roaming across different networks that may have different bandwidth allocations.

Speed and Range:

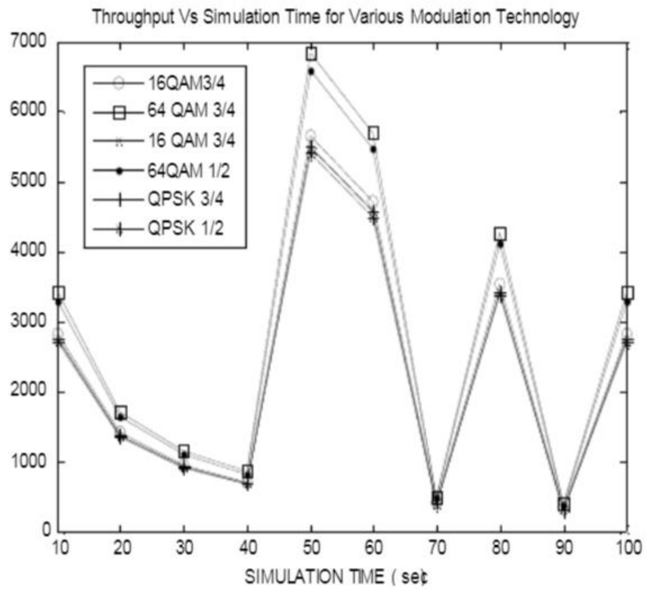
A single WiMAX antenna is expected to have a range of up to 40 miles with the speed of 70 Mbps or more.WiMAX works at 5 bps/Hz and can peak up to 100 Mbps in a 20 MHz channel

Modulation and coding:

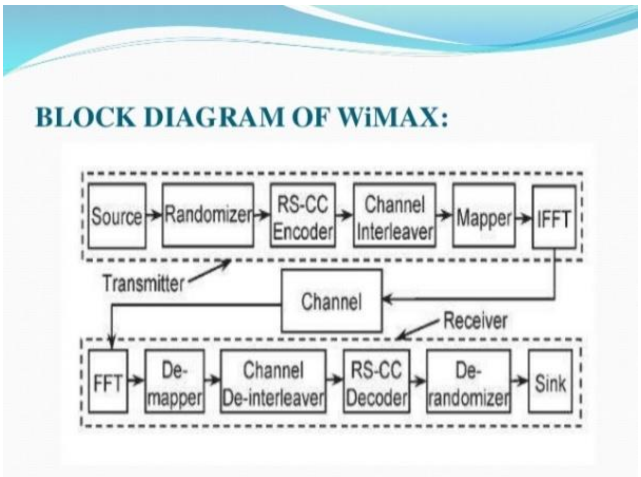
WiMAX supports a variety of modulation and coding schemes and allows for the scheme to change on a burst-by-burst basis per link, depending on channel conditions. Using the channel quality feedback indicator, the mobile can provide the base station with feedback on the downlink channel quality. For the uplink, the base station can estimate the channel quality, based on the received signal quality.

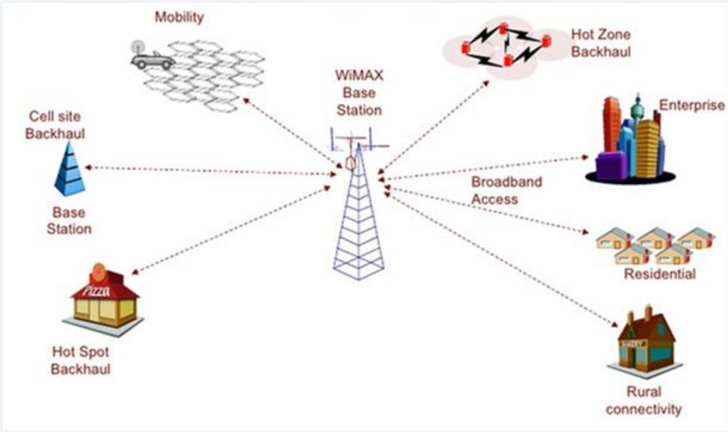
	Downlink	**Uplink**
Modulation	BPSK, QPSK, 16 QAM, 64 QAM; BPSK optional for OFDMA-PHY	BPSK, QPSK, 16 QAM; 64 QAM optional

Coding	Mandatory: convolutional codes at rate 1/2, 2/3, 3/4, 5/6 Optional: convolutional turbo codes at rate 1/2, 2/3, 3/4, 5/6; repetition codes at rate 1/2, 1/3, 1/6, LDPC, RS-Codes for OFDM-PHY	Mandatory: convolutional codes at rate 1/2, 2/3, 3/4, 5/6 Optional: convolutional turbo codes at rate 1/2, 2/3, 3/4, 5/6; repetition codes at rate 1/2, 1/3, 1/6, LDPC



Schematic View:





2. Wi-Fi (WLAN)[24][25][26]

WLAN, or wireless LAN, is a network that allows devices to connect and communicate wirelessly. devices on a WLAN communicate via Wi-Fi. It also provides a way for small devices, such as smartphones and tablets, to connect to the network. WLANs are not limited by the number of physical ports on the router and therefore can support dozens or even hundreds of devices. A WLAN can be easily upgraded by replacing routers with new versions thus it is a much easier and cheaper solution than upgrading old Ethernet cables.

Scalability:

The range of a WLAN can be anywhere from a single room to an entire campus. The range of a WLAN can easily be extended by adding one or more repeaters.

Speed:

	Theoretical	Actual
802.11b	11 Mbps	5.5 Mbps
802.11a	54 Mbps	20 Mbps

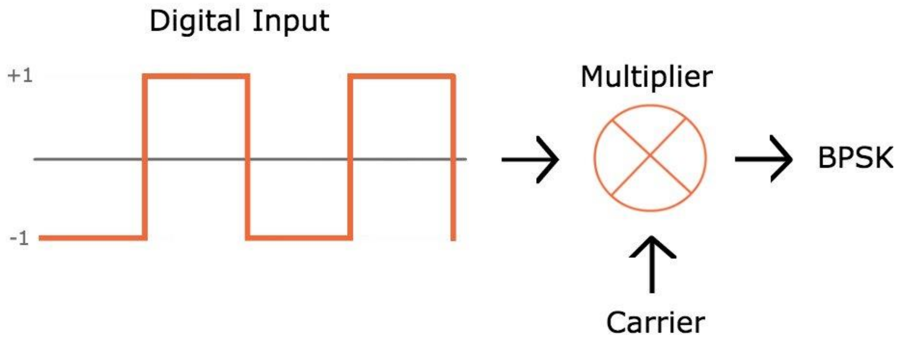
Modulation:

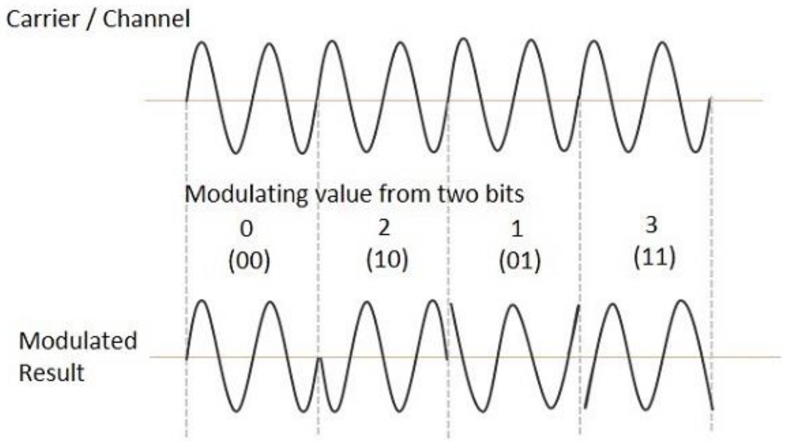
- **Radio Modulation:**

WiFi systems use two primary radio transmission techniques.

- **802.11b (<=11 Mbps)** − The 802.11b radio link uses a direct sequence spread spectrum technique called **complementary coded keying** (CCK). The bit stream is processed with a special coding and then modulated using Quadrature Phase Shift Keying (QPSK).

- **802.11a and g (<=54 Mbps)** – The 802.11a and g systems use 64-channel orthogonal frequency division multiplexing (OFDM). In an OFDM modulation system, the available radio band is divided into a number of sub-channels and some of the bits are sent on each. The transmitter encodes the bit streams on the 64 subcarriers using Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), or one of two levels of Quadrature Amplitude Modulation (16, or 64-QAM). Some of the transmitted information is redundant, so the receiver does not have to receive all of the sub-carriers to reconstruct the information.

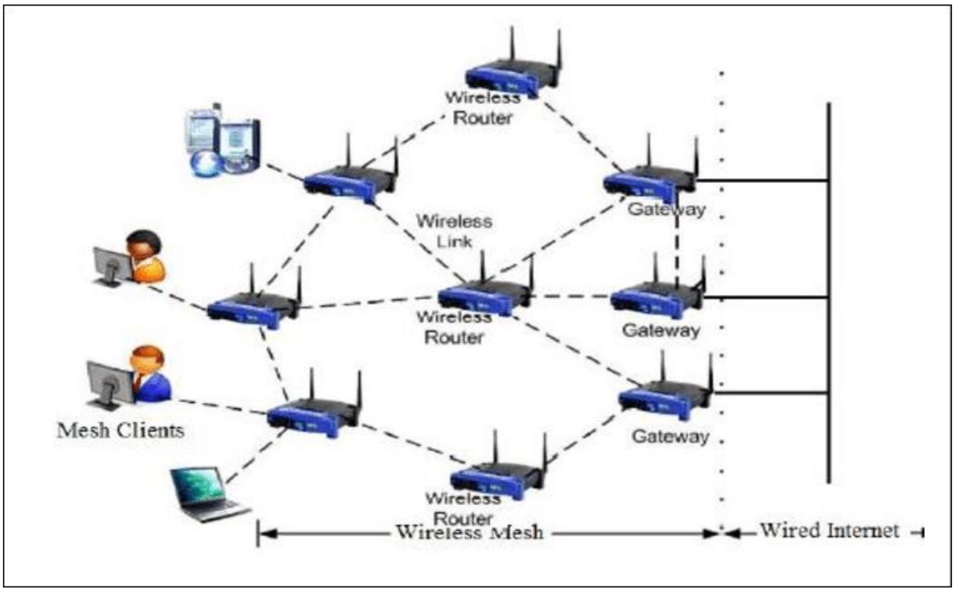




- **Adaptive Modulation:**

WiFi uses adaptive modulation and varying levels of forward error correction to optimize transmission rate and error performance. As a radio signal loses power or encounters interference, the error rate will increase. Adaptive modulation means that the transmitter will automatically shift to a more robust, though less efficient, modulation technique in those adverse conditions.

Schematic view:



3. Bluetooth (WPAN)[27][28][29]

WPANs are short-range networks that use Bluetooth technology. Bluetooth is a standard for enabling wireless communication between mobile computers, mobile phones, and portable handheld devices. The main characteristics of such a WPAN are:

- Short-range communication
- Low power consumption
- Low cost
- Small personal networks
- Communication of devices within a personal space

Scalability:

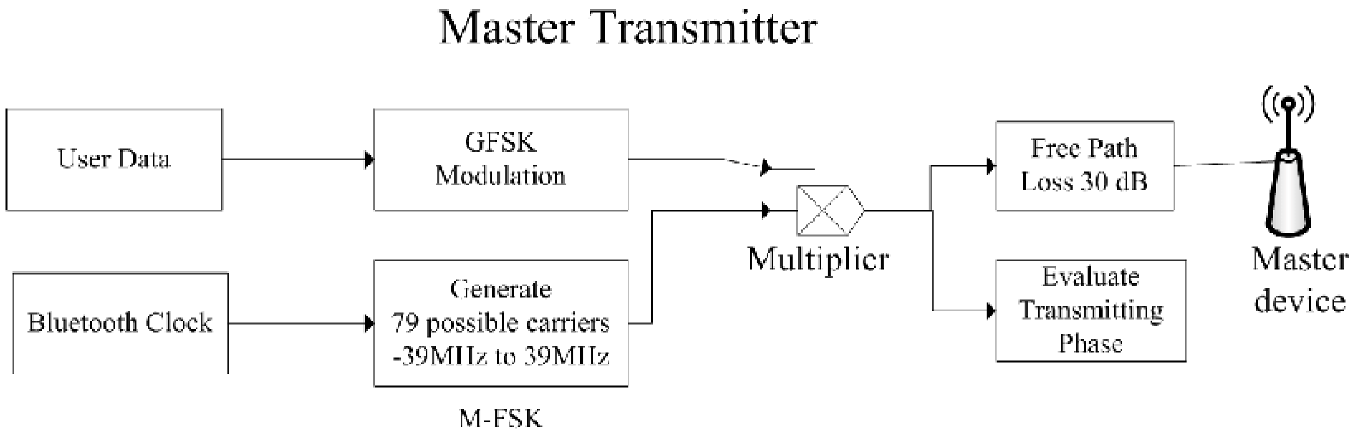
They are commonly used to interconnect compatible devices near a central location, such as a desk. A WPAN has a typical range of about 30 feet. t is able to communicate through physical barriers, typically with a range of 10 meters, although with power amplifiers, 100 meters is possible.

Speed:

Bluetooth uses the unlicensed 2.4-GHz spectrum for communication, with a peak throughput of 720 Kbps. It is expected that this throughput will increase to around 10 Mbps with future Bluetooth specifications.

Modulation:

Originally, Gaussian frequency-shift keying (GFSK) modulation was the only modulation scheme available. Since the introduction of Bluetooth 2.0+EDR, π/4-DQPSK (differential quadrature phase-shift keying) and 8-DPSK modulation may also be used between compatible devices. Devices functioning with GFSK are said to be operating in basic rate (BR) mode where an instantaneous bit rate of 1 Mbit/s is possible. The term Enhanced Data Rate (EDR) is used to describe π/4-DPSK and 8-DPSK schemes, each giving 2 and 3 Mbit/s respectively. The combination of these (BR and EDR) modes in Bluetooth radio technology is classified as a BR/EDR radio.



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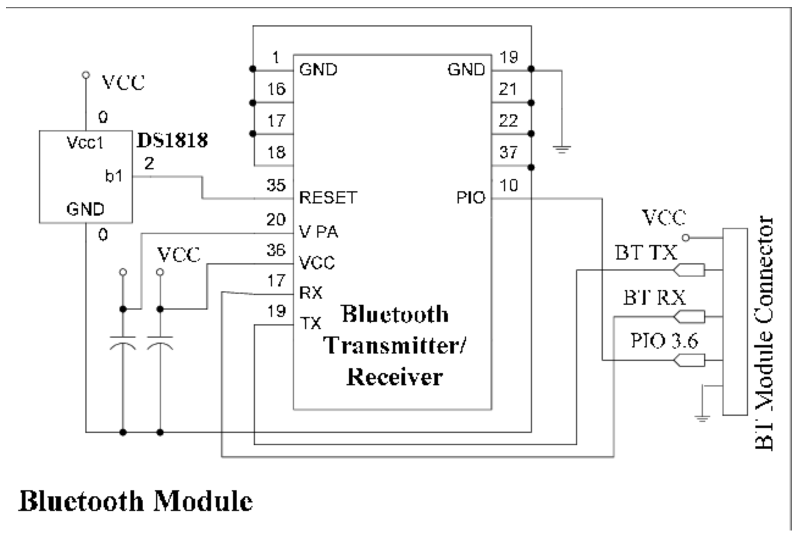


4. Zigbee[30][31][32]

Zigbee is a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power wireless IoT networks. The Zigbee standard operates on the IEEE 802.15.4 physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.

The technology defined by the Zigbee specification is intended to be simpler and less expensive than other wireless personal area networks (WPANs), such as Bluetooth or more general wireless networking such as Wi-Fi.

Scalability:

Zigbee communication is specially built for control and sensor networks on IEEE 802.15.4 standard for wireless personal area networks (WPANs). used to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection. Hence, Zigbee is a low-power, low data rate, and close proximity (i.e., personal area) wireless ad hoc network.

Speed and Range:

Zigbee is typically used in low data rate applications that require long battery life and secure networking (Zigbee networks are secured by 128 bit symmetric encryption keys.) Zigbee has a defined rate of 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device.

Its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics.[2] Zigbee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones.

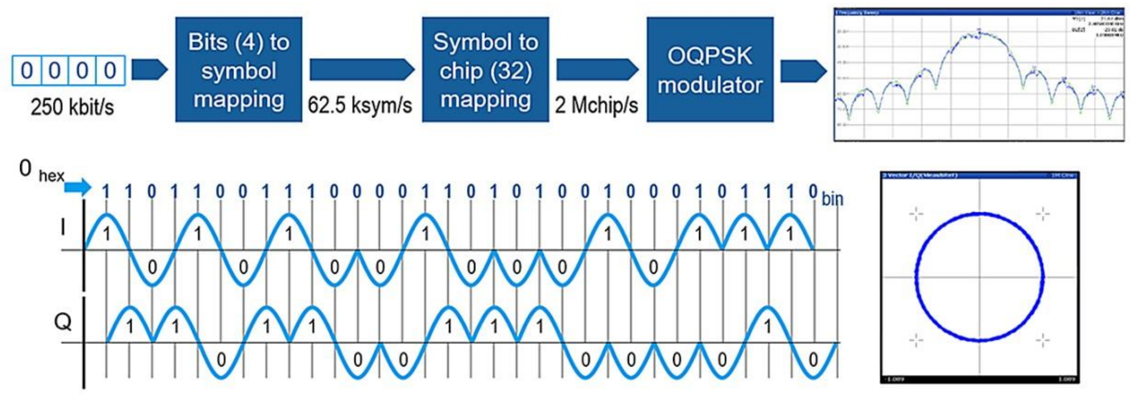
Modulation and encoding:

ZigBee uses the Direct-Sequence Spread Spectrum (DSSS) Coding instead of the normal narrow-band transmission before modulate digital stream to make the radio signal be transmitted over wider range of frequencies and more resistant to interference by expanding codes to be transmitted to be redundant ones.

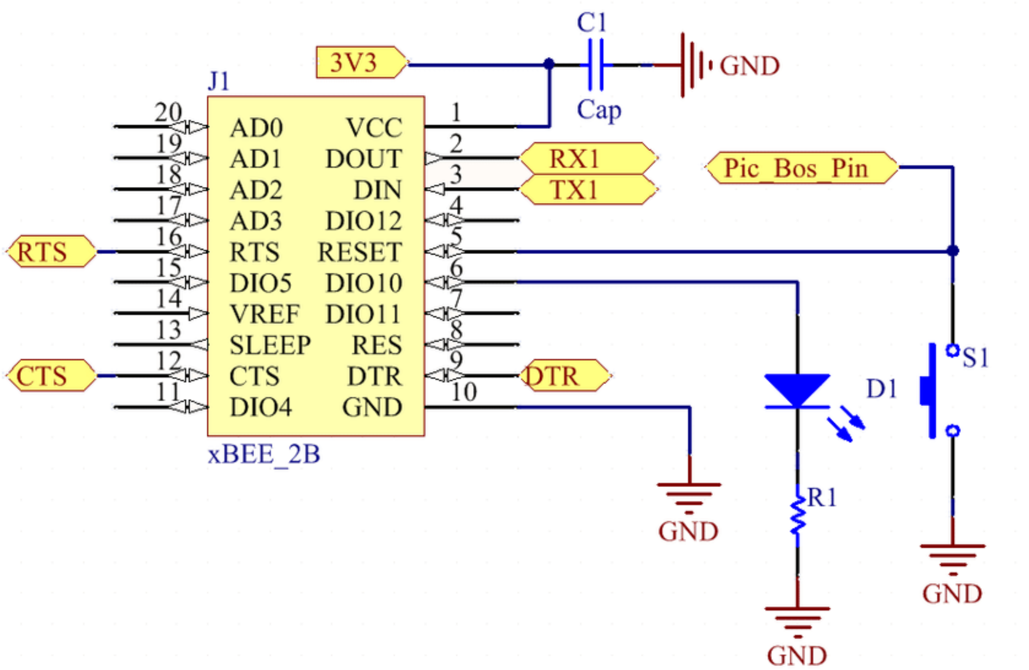
However, the signal modulation techniques used by ZigBee are varied according to the used frequencies.

For the frequency of 868 MHz, the Binary Phase Shift Keying (BPSK) is used. Although the BPSK uses 2 phases to encode signals, the DSSS coding replicates each bit to be 15 bits before using the BPSK.

For the frequency of 2405 MHz, the Offset Quadrature Phrase shift keying (OQPSK) or the Minimum Shift Keying (MSK) is used. These techniques are similar to the Quadrature Phase Shift Keying (QPSK) but it uses 2 carrier signals whose phrases are different by 90 degree. It modulates some parts of the code on one signal and the others on the other signal. Then, both signals are combined together and transmitted so that one signal element carries 2 bits of data.



Schematic view:



5. Li-Fi[33][34][35]

Li-Fi is the short form of Light Fidelity. LiFi is a mobile wireless technology that uses light rather than radio frequencies to transmit data. LiFi holds the key to solving challenges faced by 5G. LiFi can transmit at multiple gigabits, is more reliable, virtually interference free and uniquely more secure than radio technology such as Wi-Fi or cellular.

The technology is supported by a global ecosystem of companies driving the adoption of LiFi, the next generation of wireless that is ready for seamless integration into the 5G core.

Scalability:

The applications of LiFi are endless because light is available everywhere. It can be used in a meeting room environment (LAN). Since the light cannot pass through walls, the data is secure. It can also be used in intelligent transportation systems. Car headlights and tail lights offer the prospect of car-to-car communication over LiFi, allowing development of anti-collision systems and exchange of information on driving conditions between vehicles. Traffic lights already use LED lighting, so that there is also the prospect offered of city-wide traffic management systems (MAN).

Speed and Range:

Li-Fi can theoretically transmit at speeds of up to 100 Gbit/s

LiFi uses light for data transmission and covers distance of about 10 meters

Modulation and encoding:

- **Single carrier modulation**

  OOK (On-Off keying): OOK is one of the well known and simple modulation schemes, and it provides a good trade-off between system performance and implementation complexity. The 802.15.7 standard uses Manchester Coding to ensure the period of positive pulses is the same as the negative ones but this also doubles the bandwidth required for OOK transmission.

- **Multi carrier modulation:**

  Multicarrier modulation techniques offer a viable solution for high speed LiFi in terms of power efficiency, spectral efficiency and computational efficiency. In particular, orthogonal frequency division multiplexing (OFDM) based modulation techniques offer a practical solution as they are based on fast Fourier transformations for which very computational effective digital signal processing implementations exist.

  OFDM: Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. This is a new approach to transmission in which an additional dimension is added to conventional 2D amplitude/phase modulation (APM) techniques such as quadrature amplitude modulation (QAM) and amplitude shift keying (ASK).This technique splits the serial bit stream into two bit sub-streams of the same length. The key idea is to use the sub-carrier index to convey information to the receiver

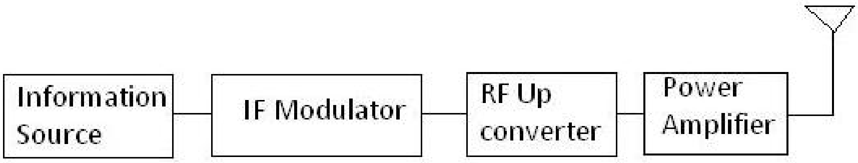


Fig.1 Single carrier system

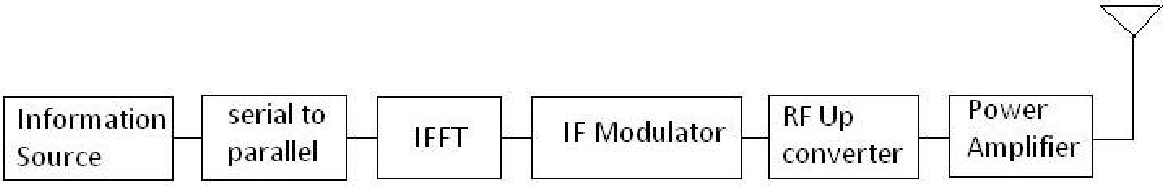
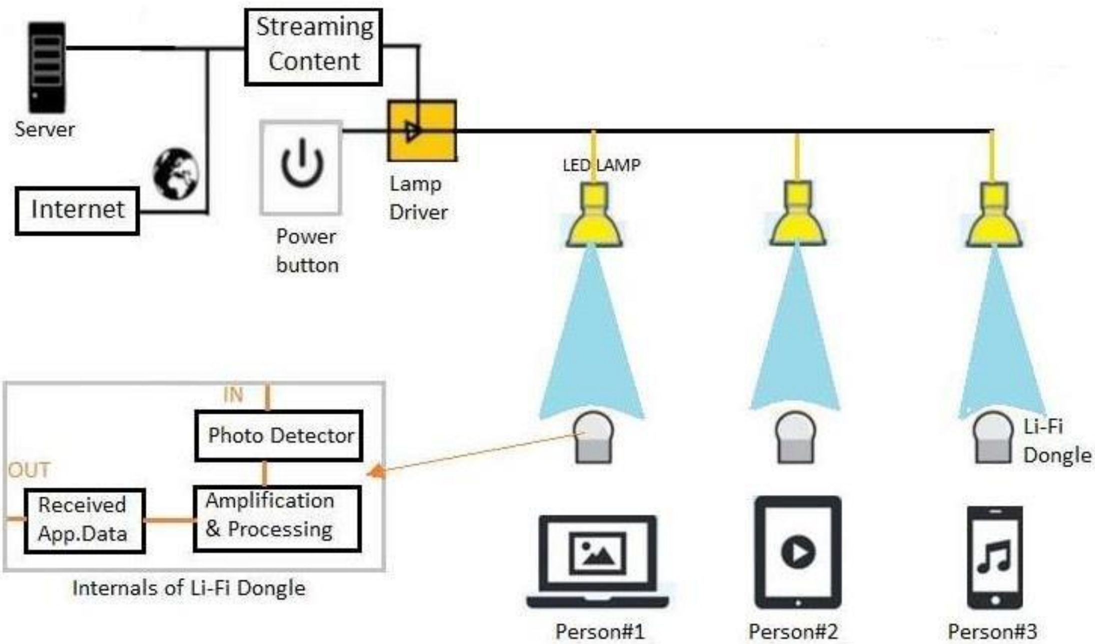


Fig. 2 OFDM based system

Schematic view:



6. NFC[36][37]

Near-field communication (NFC) is a short-range wireless technology that makes your smartphone, tablet, wearables, payment cards, and other devices even smarter.Near-field communication transmits data through electromagnetic radio fields to enable two devices to communicate with each other.

Scalability:

NFC has small applications like mobile identification, mobile payments etc. Also, NFC chips can be used to automate small tasks on devices. Since NFC utilizes point-to-point network topology between 2 devices it is not scalable to larger networks

Speed and Range:

The transmission frequency for data across NFC is 13.56 megahertz. You can send data at either 106, 212, or 424 kilobits per second.

NFC has a low range of less than 4 cm. However, it has its benefits. Passive devices like advertising tags can operate without a major power source.

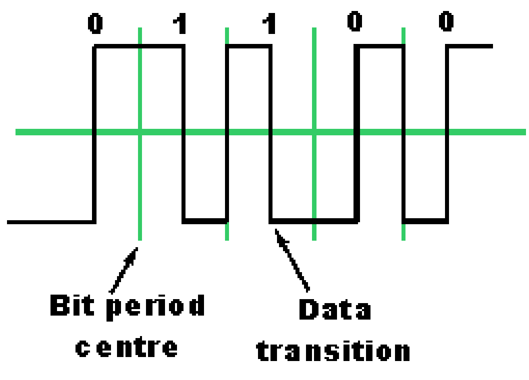
Modulation and encoding:

NFC employs two different coding systems on the RF signal to transfer data. In most cases a level of 10% modulation is used, with a Manchester coding format. However for an active device transmitting data at 106 kbps, a modified Miller coding scheme is used with 100% modulation. In all other cases Manchester coding is used with a modulation ratio of 10%.

- **Manchester encoding**

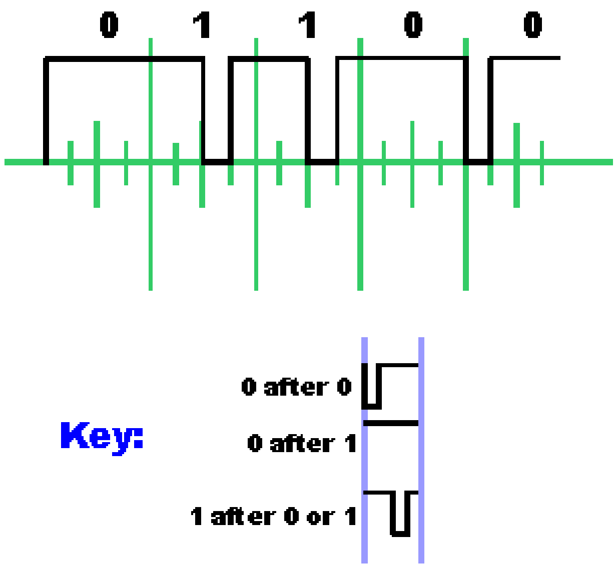
Manchester coding is used for the majority of cases for the NFC communications. The Manchester coding utilises the two different transitions that may occur at the midpoint of a period. A low-to-high transition expresses a 0 bit, whereas a high-to-low transition stands for a 1 bit.

To achieve these conditions it is sometimes necessary to have a transition at the middle of a bit period. Transitions at the beginning of period are disregarded.

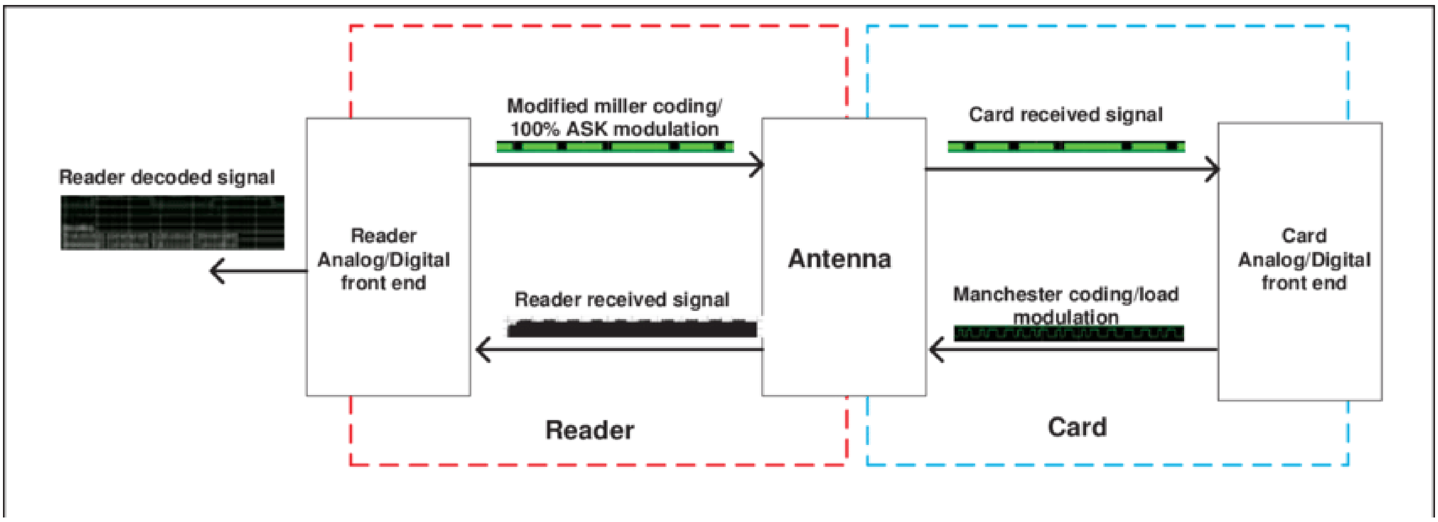


- **Modified Miller encoding**

The modified Miller code is a little less intuitive, but provides an efficient form of coding. It is characterised by the pauses occurring in the carrier at different positions of a period. Depending on the information to be transmitted, bits are coded as shown below. A high or "1" is always encoded in the same way, but a low or "0" is encoded differently dependent upon what preceded it.



<u>**Schematic view:**</u>



7. Starlink satellite constellation[38][39][40][41]

Starlink is a satellite constellation development project underway by SpaceX, to develop a low-cost, high-performance satellite bus and requisite customer ground transceivers to implement a new spaceborne Internet communication system. The constellation will consist of thousands of mass-produced small satellites in low Earth orbit (LEO), working in combination with ground transceivers.

Product development began in 2015, with the first two prototype test-flight satellites launched in February 2018. A second set of test satellites and the first large deployment of a piece of the constellation occurred in May 2019 when the first 60 operational satellites were launched. The first 60 Starlink satellites were launched on May 23, 2019, aboard a SpaceX Falcon 9 rocket. The satellites successfully reached their operational altitude of 340 miles (550 kilometers) — low enough to get pulled down to Earth by atmospheric drag in a few years so that they don't become space junk once they die. As of 2020, SpaceX is launching 60 satellites at a time, aiming to deploy 1,584 of the 260 kilograms (570 lb) spacecraft to provide near-global service by late 2021 or 2022.[10] SpaceX is targeting a private beta service in the Northern United States and Canada by August 2020 with a public beta following in November 2020, service beginning at high latitudes between 44°-52° North

How Starlink internet will work

- Starlink satellites will sit closer to the Earth to reduce latency and use lasers to boost internet speeds.
- Starlink satellites will sit about 342 miles above the Earth's surface.[4] That's much closer than other satellites, which means there's much less distance for your internet signal to travel to a Starlink satellite.
- Each Starlink satellite will communicate with four other satellites using lasers. That means they'll beam data across the globe at almost the speed of light—a speed that only fiber-optic internet comes close to matching.

How fast Starlink internet will be

According to SpaceX, Starlink will offer speeds of up to a gigabit per second at latencies from 25 milliseconds to 35 milliseconds.
Those latencies would make SpaceX's service comparable to cable and fiber, while existing satellite broadband services have latencies of 600 ms or more, according to FCC measurements.

Keeping space clean

In a filing to the Federal Communications Commission (FCC), SpaceX is asking the agency to modify its license so that more than 1,500 Starlink satellites can operate at an altitude 600 kilometers lower than the company originally requested.
SpaceX says moving the satellites to a lower altitude means it can do more with less.
Lower altitude makes it easy to dispose of these satellites once they're done in space. At this height, particles from Earth's atmosphere bombard the spacecraft more rapidly, pushing

them out of orbit and dragging them down to the planet. And on the way down, they burn up in the atmosphere.

Making sure these spacecraft come out of orbit in a timely manner is crucial because of the vast number of vehicles that SpaceX wants to put into orbit. A constellation the size of Starlink could dramatically increase the number of operational satellites in space, raising the risk of in-space collisions. A recent NASA study argued that 99 percent of these satellites will need to be taken out of orbit, reliably, within five years of launch, or the risk of satellite collisions goes up quite a bit.

The atmosphere at 550 kilometers should do the job within a few years. This is helpful in case the spacecraft fails in orbit. Satellites that fail in higher altitudes could turn into unoperational space debris that stay in orbit for long periods of time. At lower altitudes, they can still fail, and the atmosphere will still swallow them up in a timely manner.

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